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PATENT APPLICATION OF

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ENTITLED

ELECTRONIC BATTERY TESTER CABLE

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ELECTRONIC BATTERY TESTER CABLE

The present application is a Continuation-In-Part of and claims priority of U.S. patent application Serial No. 10/396,550, filed March 25, 2003, the content of which is hereby incorporated by reference in its entirety.

BACKGROUND OF THE INVENTION

The present invention relates to testing of storage batteries. More specifically, the present invention relates to an electronic battery tester capable of detecting the type of cable to which it is connected.

Storage batteries, such as lead acid storage batteries of the type used in the automotive industry, have existed for many years. However, understanding the nature of such storage batteries, how such storage batteries operate and how to accurately test such batteries has been an ongoing endeavor and has proved quite difficult. Storage batteries consist of a plurality of individual storage cells electrically connected in series. Typically each cell has a voltage potential of about 2.1 volts. By connecting the cells in series, the voltages of the individual cells are added in a cumulative manner. For example, in a typical automotive storage battery, six storage cells are used to provide a total voltage when the battery is fully charged of 12.6 volts.

There has been a long history of attempts to accurately test the condition of storage batteries. A simple test is to measure the voltage of the battery. If the voltage is below a certain threshold, the battery is determined to be bad. However, this test is

inconvenient because it requires the battery to be charged prior to performing the test. If the battery is discharged, the voltage will be low and a good battery may be incorrectly tested as bad. Furthermore, such a test does not give any indication of how much energy is stored in the battery. Another technique for testing a battery is referred as a load test. In a load test, the battery is discharged using a known load. As the battery is discharged, the voltage across the battery is monitored and used to determine the condition of the battery. This technique requires that the battery be sufficiently charged in order that it can supply current to the load.

More recently, a technique has been pioneered by Dr. Keith S. Champlin and Midtronics, Inc. for testing storage batteries by measuring the conductance of the batteries. This technique is described in a number of United States patents, for example, U.S. Patent No. 3,873,911, issued March 25, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 3,909,708, issued September 30, 1975, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,816,768, issued March 28, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE; U.S. Patent No. 4,825,170, issued April 25, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH AUTOMATIC VOLTAGE SCALING; U.S. Patent No. 4,881,038, issued November 14, 1989, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH

AUTOMATIC VOLTAGE SCALING TO DETERMINE DYNAMIC CONDUCTANCE; U.S. Patent No. 4,912,416, issued March 27, 1990, to Champlin, entitled ELECTRONIC BATTERY TESTING DEVICE WITH STATE-OF-CHARGE COMPENSATION; U.S. Patent No. 5,140,269, issued August 18, 1992, to Champlin, entitled ELECTRONIC TESTER FOR ASSESSING BATTERY/CELL CAPACITY; U.S. Patent No. 5,343,380, issued August 30, 1994, entitled METHOD AND APPARATUS FOR SUPPRESSING TIME VARYING SIGNALS IN BATTERIES UNDERGOING CHARGING OR DISCHARGING; U.S. Patent No. 5,572,136, issued November 5, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,574,355, issued November 12, 1996, entitled METHOD AND APPARATUS FOR DETECTION AND CONTROL OF THERMAL RUNAWAY IN A BATTERY UNDER CHARGE; U.s. Patent No. 5,585,416, issued December 10, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,585,728, issued December 17, 1996, entitled ELECTRONIC BATTERY TESTER WITH AUTOMATIC COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,589,757, issued December 31, 1996, entitled APPARATUS AND METHOD FOR STEP-CHARGING BATTERIES TO OPTIMIZE CHARGE ACCEPTANCE; U.S. Patent No. 5,592,093, issued January 7, 1997, entitled ELECTRONIC BATTERY TESTING DEVICE LOOSE TERMINAL CONNECTION DETECTION VIA A COMPARISON CIRCUIT; U.S. Patent No. 5,598,098, issued January 28, 1997, entitled ELECTRONIC BATTERY TESTER WITH VERY HIGH NOISE IMMUNITY; U.S. Patent No.

5,656,920, issued August 12, 1997, entitled METHOD FOR OPTIMIZING THE CHARGING LEAD-ACID BATTERIES AND AN INTERACTIVE CHARGER; U.S. Patent No. 5,757,192, issued May 26, 1998, entitled METHOD AND APPARATUS FOR DETECTING A BAD CELL IN A STORAGE BATTERY; U.S. Patent No. 5,821,756, issued October 13, 1998, entitled ELECTRONIC BATTERY TESTER WITH TAILORED COMPENSATION FOR LOW STATE-OF-CHARGE; U.S. Patent No. 5,831,435, issued November 3, 1998, entitled BATTERY TESTER FOR JIS STANDARD; U.S. Patent No. 5,914,605, issued June 22, 1999, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 5,945,829, issued August 31, 1999, entitled MIDPOINT BATTERY MONITORING; U.S. Patent No. 6,002,238, issued December 14, 1999, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,037,751, issued March 14, 2000, entitled APPARATUS FOR CHARGING BATTERIES; U.S. Patent No. 6,037,777, issued March 14, 2000, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,051,976, issued April 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,081,098, issued June 27, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,091,245, issued July 18, 2000, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Patent No. 6,104,167, issued August 15, 2000, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,137,269, issued October 24, 2000, entitled METHOD AND

APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,163,156, issued December 19, 2000, entitled ELECTRICAL CONNECTION FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,172,483, issued January 9, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX IMPEDANCE OF CELL AND BATTERIES; U.S. Patent No. 6,172,505, issued January 9, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,222,369, issued April 24, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Patent No. 6,225,808, issued May 1, 2001, entitled TEST COUNTER FOR ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,249,124, issued June 19, 2001, entitled ELECTRONIC BATTERY TESTER WITH INTERNAL BATTERY; U.S. Patent No. 6,259,254, issued July 10, 2001, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,262,563, issued July 17, 2001, entitled METHOD AND APPARATUS FOR MEASURING COMPLEX ADMITTANCE OF CELLS AND BATTERIES; U.S. Patent No. 6,294,896, issued September 25, 2001; entitled METHOD AND APPARATUS FOR MEASURING COMPLEX SELF-IMMITANCE OF A GENERAL ELECTRICAL ELEMENT; U.S. Patent No. 6,294,897, issued September 25, 2001, entitled METHOD AND APPARATUS FOR ELECTRONICALLY EVALUATING THE INTERNAL TEMPERATURE OF AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,304,087, issued October 16, 2001, entitled APPARATUS

FOR CALIBRATING ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,310,481, issued October 30, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,313,607, issued November 6, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Patent No. 6,313,608, issued November 6, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,316,914, issued November 13, 2001, entitled TESTING PARALLEL STRINGS OF STORAGE BATTERIES; U.S. Patent No. 6,323,650, issued November 27, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,329,793, issued December 11, 2001, entitled METHOD AND APPARATUS FOR CHARGING A BATTERY; U.S. Patent No. 6,331,762, issued December 18, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Patent No. 6,332,113, issued December 18, 2001, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,351,102, issued February 26, 2002, entitled AUTOMOTIVE BATTERY CHARGING SYSTEM TESTER; U.S. Patent No. 6,359,441, issued March 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,363,303, issued March 26, 2002, entitled ALTERNATOR DIAGNOSTIC SYSTEM, U.S. Patent No. 6,392,414, issued May 21, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,417,669, issued July 9, 2002, entitled SUPPRESSING INTERFERENCE IN AC MEASUREMENTS OF CELLS, BATTERIES AND OTHER ELECTRICAL ELEMENTS; U.S. Patent No. 6,424,158, issued July 23, 2002, entitled APPARATUS AND METHOD FOR CARRYING OUT DIAGNOSTIC TESTS ON BATTERIES AND FOR

RAPIDLY CHARGING BATTERIES; U.S. Patent No. 6,441,585, issued August 17, 2002, entitled APPARATUS AND METHOD FOR TESTING RECHARGEABLE ENERGY STORAGE BATTERIES; U.S. Patent No. 6,445,158, issued September 3, 2002, entitled VEHICLE ELECTRICAL SYSTEM TESTER WITH ENCODED OUTPUT; U.S. Patent No. 6,456,045, issued September 24, 2002, entitled INTEGRATED CONDUCTANCE AND LOAD TEST BASED ELECTRONIC BATTERY TESTER; U.S. Patent No. 6,466,025, issued October 15, 2002, entitled ALTERNATOR TESTER; U.S. Patent No. 6,466,026, issued October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Serial No. 09/703,270, filed October 31, 2000, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 09/780,146,filed February 9, 2001, entitled STORAGE BATTERY WITH INTEGRAL BATTERY TESTER; U.S. Serial No. 09/816,768, filed March 23, 2001, entitled MODULAR BATTERY TESTER; U.S. Serial No. 09/756,638, filed January 8, 2001, entitled METHOD AND APPARATUS FOR DETERMINING BATTERY PROPERTIES FROM COMPLEX IMPEDANCE/ADMITTANCE; U.S. Serial No. 09/862,783, filed May 21, 2001, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 09/960,117, filed September 20, 2001, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 09/908,389, filed July 18, 2001, entitled BATTERY CLAMP WITH INTEGRATED CIRCUIT SENSOR; U.S. Serial No. 09/908,278, filed July 18, 2001, entitled BATTERY CLAMP WITH EMBEDDED ENVIRONMENT SENSOR; U.S.

Serial No. 09/880,473, filed June 13, 2001; entitled BATTERY TEST MODULE; U.S. Serial No. 09/940,684, filed August 27, 2001, entitled METHOD AND APPARATUS FOR EVALUATING STORED CHARGE IN AN ELECTROCHEMICAL CELL OR BATTERY; U.S. Serial No. 60/330,441, filed October 17, 2001, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/348,479, filed October 29, 2001, entitled CONCEPT FOR TESTING HIGH POWER VRLA BATTERIES; U.S. Serial No. 10/046,659, filed October 29, 2001, entitled ENERGY MANAGEMENT SYSTEM FOR AUTOMOTIVE VEHICLE; U.S. Serial No. 09/993,468, filed November 14, 2001, entitled KELVIN CONNECTOR FOR A BATTERY POST; U.S. Serial No. 09/992,350, filed November 26, 2001, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/341,902, filed December 19, 2001, entitled BATTERY TESTER MODULE; U.S. Serial No. 10/042,451, filed January 8, 2002, entitled BATTERY CHARGE CONTROL DEVICE, U.S. Serial No. 10/073,378, filed February 8, 2002, entitled METHOD AND APPARATUS USING A CIRCUIT MODEL TO EVALUATE CELL/BATTERY PARAMETERS; U.S. Serial No. 10/093,853, filed March 7, 2002, entitled ELECTRONIC BATTERY TESTER WITH NETWORK COMMUNICATION; U.S. Serial No. 60/364,656, filed March 14, 2002, entitled ELECTRONIC BATTERY TESTER WITH LOW TEMPERATURE RATING DETERMINATION; U.S. Serial No. 10/098,741, filed March 14, 2002, entitled METHOD AND APPARATUS FOR AUDITING A BATTERY TEST; U.S. Serial No. 10/101,543, filed March 19, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/112,114, filed March

28, 2002; U.S. Serial No. 10/109,734, filed March 28, 2002; U.S. Serial No. 10/112,105, filed March 28, 2002, entitled CHARGE CONTROL SYSTEM FOR A VEHICLE BATTERY; U.S. Serial No. 10/112,998, filed March 29, 2002, entitled BATTERY TESTER WITH BATTERY REPLACEMENT OUTPUT; U.S. Serial No. 10/119,297, filed April 9, 2002, entitled METHOD AND APPARATUS FOR TESTING CELLS AND BATTERIES EMBEDDED IN SERIES/PARALLEL SYSTEMS; U.S. Serial No. 10/128,790, filed April 22, 2002, entitled METHOD OF DISTRIBUTING JUMP-START BOOSTER PACKS; U.S. Serial No. 60/379,281, filed May 8, 2002, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE; U.S. Serial No. 10/143,307, filed May 10, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 60/387,046, filed June 7, 2002, entitled METHOD AND APPARATUS FOR INCREASING THE LIFE OF A STORAGE BATTERY; U.S. Serial No. 10/177,635, filed June 21, 2002, entitled BATTERY CHARGER WITH BOOSTER PACK; U.S. Serial No. 10/207,495, filed July 29, 2002, entitled KELVIN CLAMP FOR ELECTRICALLY COUPLING TO A BATTERY CONTACT; U.S. Serial No. 10/200,041, filed July 19, 2002, entitled AUTOMOTIVE VEHICLE ELECTRICAL SYSTEM DIAGNOSTIC DEVICE; U.S. Serial No. 10/217,913, filed August 13, 2002, entitled, BATTERY TEST MODULE; U.S. Serial No. 60/408,542, filed September 5, 2002, entitled BATTERY TEST OUTPUTS ADJUSTED BASED UPON TEMPERATURE; U.S. Serial No. 10/246,439, filed September 18, 2002, entitled BATTERY TESTER UPGRADE USING SOFTWARE KEY; U.S. Serial No. 60/415,399, filed October 2, 2002,

entitled QUERY BASED ELECTRONIC BATTERY TESTER; and U.S. Serial No. 10/263,473, filed October 2, 2002, entitled ELECTRONIC BATTERY TESTER WITH RELATIVE TEST OUTPUT; U.S. Serial No. 60/415,796, filed October 3, 2002, entitled QUERY BASED ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/271,342, filed October 15, 2002, entitled IN-VEHICLE BATTERY MONITOR; U.S. Serial No. 10/270,777, filed October 15, 2002, entitled PROGRAMMABLE CURRENT EXCITER FOR MEASURING AC IMMITTANCE OF CELLS AND BATTERIES; U.S. Serial No. 10/310,515, filed December 5, 2002, entitled BATTERY TEST MODULE; U.S. Serial No. 10/310,490, filed December 5, 2002, entitled ELECTRONIC BATTERY TESTER; U.S. Serial No. 10/310,385, filed December 5, 2002, entitled BATTERY TEST MODULE, U.S. Serial No. 60/437,255, filed December 31, 2002, entitled REMAINING TIME PREDICTIONS, U.S. Serial No. 60/437,224, filed December 31, 2002, entitled DISCHARGE VOLTAGE PREDICTIONS, U.S. Serial No. 10/349,053, filed January 22, 2003, entitled APPARATUS AND METHOD FOR PROTECTING A BATTERY FROM OVERDISCHARGE, U.S. Serial No. 10/388,855, filed March 14, 2003, entitled ELECTRONIC BATTERY TESTER WITH BATTERY FAILURE TEMPERATURE DETERMINATION, U.S. Serial No. 10/396,550, filed March 25, 2003, entitled ELECTRONIC BATTERY TESTER, U.S. Serial No. 60/467,872, filed May 5, 2003, entitled METHOD FOR DETERMINING BATTERY STATE OF CHARGE, which are incorporated herein in their entirety.

SUMMARY OF THE INVENTION

A cable for use with an electronic battery tester including electrical connections configured to electrically couple to a first terminal and a second terminal of the battery. A memory is configured to store digital data. Electrical terminals are configured to couple the first and second electrical connections and the memory to the electronic battery tester. The invention also includes a battery tester configured to couple such a cable.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of a battery tester coupled to a battery via a cable in accordance with an illustrative embodiment of the present invention.

Figure 2 is a block diagram illustrating data stored in battery tester memory in accordance with an embodiment of the present invention.

Figure 3 is a block diagram of a battery tester coupled to a battery via a cable in accordance with an illustrative embodiment of the present invention.

Figure 4 is a block diagram illustrating different components of test circuitry within the battery tester of Figures 1 and 3.

Figure 5 is a flow chart of a system for detecting a type of cable through which a battery tester is connected to a battery in accordance an embodiment of the present invention.

Figure 6 is a simplified diagram showing a cable for coupling to a battery tester which includes a memory in accordance with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention includes an electronic battery tester which communicates with a cable through which it is coupled to a battery. The tester can select a calibration value, suitable for the cable. The present invention also includes a cable for coupling a battery to a battery tester, wherein the cable includes a characteristic that is detectable by the tester.

Figure 1 is a very simplified block diagram of a battery tester 10 coupled to a battery 12 via a cable 14 in accordance with an illustrative embodiment of the present invention. The same reference numerals are used in the various figures to represent the same or similar elements. Note that Figure 1 is a simplified block diagram of a specific type of battery tester. However, the present invention is applicable to any type of battery tester including those which do not use dynamic parameters. Other types of example testers include testers that conduct load tests, current based tests, voltage based tests, tests which apply various conditions or observe various performance parameters of a battery, etc. Battery tester 10 includes an input 16, a test circuit 18, a memory 20 and an output 22. Test circuit 18 includes a microprocessor system 24 and

other circuitry, shown in Figure 4, configured to measure a dynamic parameter of battery 12. As used herein, a dynamic parameter is one which is related to a signal having an alternating current (AC) component. The signal can be either applied directly or drawn from battery 12. Example dynamic parameters include dynamic resistance, conductance, impedance, admittance, etc. This list is not exhaustive, for example, a dynamic parameter can include a component value of an equivalent circuit of battery 12. Microprocessor system 24 controls the operation of other components within test circuitry 18 and, in turn, carries out different battery testing functions based upon battery testing instructions stored in memory 20.

As can be seen in Figure 1, battery tester 10 is coupled to battery 12 with the help of cable 14. In the embodiment shown in Figure 1, cable 14 includes a four-point connection known as a Kelvin connection formed by connections 26 and 28. With such a Kelvin connection, two couplings are provided to the positive and negative terminals of battery 12. First Kelvin connection 26 includes a first conductor 26A and a second conductor 26B, which couple to tester input 16 via plug 30. Similarly, first conductor 28A and second conductor 28B of second Kelvin connection 28 also couple to tester input 16 via plug 30. As can be seen in Figure 1, plug 30 of cable 14 further includes a cable identification conductor 32 that also connects to battery tester input 16. Employing Kelvin connections

26 and 28 allows one of the electrical connections on each side of battery 12 to carry large amounts of current while the other pair of connections can be used to obtain accurate voltage readings. Note that in other embodiments of the present invention, instead of employing Kelvin connections 26 and 28, cable 14 can include a single conductor to couple the first battery terminal to tester 10 and a single conductor to couple the second battery terminal to tester 10. Details regarding testing battery 12 with the help of Kelvin connections 26 and 28 are provided further below in connection with Figure 4.

As mentioned above, different types of cables 14 may be required when different types of batteries 12 are tested using tester 10. In accordance with the present invention, tester 10 detects the type of cable 14 through which it is coupled to battery 12. Tester 10 then selects a calibration value, suitable for detected cable 14, from a plurality of calibration values stored in memory 20 and tests battery 12 through cable 14 as a function of the selected calibration value. Tester 10 identifies cable 14 with the help of a cable identification characteristic 34 included in cable identification conductor 32 and contained in memory 20. As shown in Figure 2, memory 20 includes a plurality of stored cable identification characteristics 36-40, each of the stored cable identification characteristics corresponding to a different cable. As mentioned

above, memory 20 also contains a plurality of calibration values 41-45, each different calibration value of the plurality of calibration values 41-45 corresponds to a different identification characteristic of the plurality of identification characteristics 36-40. For example, calibration value 41 corresponds to identification characteristic 36, calibration value 42 corresponds to identification characteristic 37, etc.

During operation, microprocessor system 24 of tester 10 provides a cable detection supply voltage, V_{IDS}, between ends of cable identification conductor 32 and conductor 28B, which couple to input 16 of tester 10. For simplification, components such as pull up and/or pull down resistors and other power supply circuitry that may be employed to provide V_{IDS} are not shown. An electrical response of cable test circuit 33, formed by cable identification conductor 32, including identification characteristic 34, and conductor 28B, to V_{IDS} is utilized by microprocessor system 18 to identify cable 14. Specifically, microprocessor system 18 can utilize one or more voltage and/or current measurements, for example, obtained from voltage and/or current sensor(s) (not shown) suitably coupled to cable test circuit 33 and to microprocessor system 18 to determine characteristic 34 of cable identification conductor 32. Upon determining characteristic 34, microprocessor system 18 compares determined

characteristic 34 with different individual stored characteristics of the plurality of stored characteristics. If a match is detected between a particular stored characteristic and detected characteristic 34, microprocessor 18 utilizes the calibration value corresponding to the detected and matched characteristic in computations that it carries out to determine the condition of battery 12. For example, if microprocessor system 18 determines that detected characteristic 34 matches stored identification characteristic 37, it tests battery 12 as a function of calibration value 42, which corresponds to stored identification characteristic 37. If no match is obtained, a default calibration value may be used or a message may be displayed to the user via output 22 indicating that tester 10 cannot recognize the cable that it is coupled to.

Figure 3 is a simplified block diagram of the present invention, wherein characteristic 34 is a resistor having a particular resistance value. As described above, in operation, voltage V_{IDS} is applied to cable test circuit 33. Therefore, the voltage across resistor 34 and the current flowing through cable identification conductor 32 is measured by voltage and current sensors (not shown) coupled to microprocessor system 24. Microprocessor system 34 determines the resistance of resistor 34 and compares the determined resistance value with stored identification characteristics 36-40, which are

different resistance values, each corresponding to a different cable 14 connected to tester 10. If a match is obtained between the determined resistance value and one of the stored resistance values 36-40, tester 10 tests battery 12 as a function of the calibration value corresponding to the detected and matched resistance value. If no match is obtained, a default calibration value is used or a suitable message is displayed via output 22 as described above in connection with Figure 1.

Instead of a resistor, identification characteristic 34 can comprise an inductor, a capacitor, a transponder, a Zener diode, a current source, etc., or a suitable combination of these components that have different electrical values. V_{IDS} may be an AC or DC voltage. Although cable test circuit 33 (Figures 1 and 3) is shown as being formed by cable identification conductor 32 coupled to Kelvin conductor 28B, cable identification conductor 32 may be coupled to any one of conductors 26A, 26B, 28A and 28B. Further, in embodiments of the present invention, instead of employing a Kelvin conductor to complete cable test circuit 33, an additional conductor may be employed to thereby provide a cable test circuit that is independent of the Kelvin conductors. In general, any means for identifying and recognizing cable 14, including sending and receiving digital messages with cable identification information, may be employed in the present

invention. In embodiments of the present invention, plug 30 includes a memory 35 configured to store and to provide identification characteristic 33 to tester 10.

Figure 4 is a simplified block diagram of electronic battery tester circuitry 10 in accordance with a specific embodiment of the present invention. In addition to input 16, memory 20, output 22 and microprocessor system 24, tester 10 also includes current source 50, differential amplifier 52 and analog-to-digital converter 54. Current source 50 provides one example of a forcing function for use with the invention. Amplifier 52 is capacitively coupled to battery 12 through capacitors C_1 and C_2. Amplifier 52 has an output connected to an input of analog-to-digital converter 54 which in turn has an output connected to microprocessor system 24. Microprocessor system 24 is also capable of receiving an input from input device 68.

As described above, tester 10 detects the type of cable that it is connected to and accordingly selects a suitable calibration value to be utilized for testing battery 12. During testing of battery 12, current source 50 is controlled by microprocessor system 24 and provides a current I in the direction shown by the arrow in Figure 4. In one embodiment, this is a sine wave, square wave or a pulse. Differential amplifier 52 is connected to terminals 13 and 15 of battery 12 through capacitors C_1 and C_2, respectively,

and provides an output related to the voltage potential difference between terminals 13 and 15. In a preferred embodiment, amplifier 52 has a high input impedance. Tester 10 includes differential amplifier 70 having inverting and noninverting inputs connected to terminals 13 and 15, respectively. Amplifier 70 is connected to measure the open circuit potential voltage (V_{BAT}) of battery 12 between terminals 13 and 15 and is one example of a dynamic response sensor used to sense the time varying response of the battery 12 to the applied time varying forcing function. The output of amplifier 70 is provided to analog-to-digital converter 54 such that the voltage across terminals 13 and 15 can be measured by microprocessor system 24. The output of differential amplifier 52 is converted to a digital format and is provided to microprocessor system 24. Microprocessor system 24 operates at a frequency determined by system clock 58 and in accordance with programmable instructions stored in memory 20.

Microprocessor system 24 determines the conductance of battery 12 by applying a current pulse I using current source 50. This measurement provides a dynamic parameter related to the battery. Of course, any such dynamic parameter can be measured including resistance, admittance, impedance or their combination along with conductance. Further, any type of time varying signal can be used to obtain the dynamic parameter. The signal can be generated using an active forcing function or using a forcing function which

provides a switchable load, for example, coupled to the battery 12. The processing circuitry determines the change in battery voltage due to the current pulse I using amplifier 52 and analog-to-digital converter 54. The value of current I generated by current source 50 is known and is stored in memory 20. In one embodiment, current I is obtained by applying a load to battery 12. Microprocessor system 24 calculates the conductance of battery 12 using the following equation:

$$G_{BAT} = \frac{\Delta I}{\Delta V}$$

Equation 1

where ΔI is the change in current flowing through battery 12 due to current source 50 and ΔV is the change in battery voltage due to applied current ΔI. Based upon the battery conductance G_{BAT} and the battery voltage, the battery tester 10 determines the condition of battery 12. Battery tester 10 is programmed with information which can be used with the determined battery conductance and voltage as taught in the above listed patents to Dr. Champlin and Midtronics, Inc.

The tester can compare the measured CCA (Cold Cranking Amp) with the rated CCA for that particular battery. Additional information relating to the conditions of the battery test can be received by microprocessor system 24 from input device 68. Input device 68 may comprise one or more sensors, for example, or other elements which provide information such as ambient or battery temperature, time, date,

humidity, barometric pressure, noise amplitude or characteristics of noise in the battery or in the test result, or any other information or data which may be sensed or otherwise recovered which relates to the conditions of the test how the battery test was performed, or intermediate results obtained in conducting the test.

As mentioned above, cable 14 includes a first Kelvin connection 26, which has a first conductor 26A and a second conductor 26B, and a second Kelvin connection 28, which has a first conductor 28A and second conductor 28B, and a plug 30 through which these conductors pass. However, more specifically, each Kelvin connector or connection (such as 26, 28) includes a first and second conductor, each of which is coupled to a connector of plug 30. Further, in some embodiments, cable 14 is a part of tester 10. Consequently, a specific embodiment of the present invention is directed to an electronic battery tester (such as 10) for testing a storage battery (such as 12) in which a first and second Kelvin connector (such as 26, 28) are configured to electrically couple to terminals of the battery (such as 12). Also included, is a plug (such as 30) having a first connector coupled to a first conductor of the first Kelvin connector, a second connector coupled to a second conductor of the first Kelvin connector, a third connector coupled to a first conductor of the second Kelvin connector, a fourth connector coupled

to a second conductor of the second Kelvin connector, and a cable identification connector. A memory (such as 20) contains a first and a second calibration value. Test circuitry (such as 18), coupled to the first and second Kelvin connectors through the plug (such as 30), tests the storage battery as a function of the first calibration value if the cable identification connector has a first electrical value and as a function of the second calibration value if the cable identification connector has a second electrical value.

Figure 5 is a flow chart 100 of a system for detecting a type of cable through which a battery tester is connected to a battery in accordance with an embodiment of the present invention. At step 102, an input configured to couple to terminals of a battery via any one of a plurality of cables is provided. At step 104, a plurality of calibration values, each calibration value of the plurality values corresponding to a different one of the plurality of cables is provided. At step 106, the input is coupled to the terminals of the battery via one of plurality of cables. At step 108, one of the plurality of cables that is coupled to the input is detected. At step 110, the battery is tested via the input, as a function of one of the plurality of calibration values corresponding to the detected one of the plurality of cables. Different techniques, some of which are set forth above, can be employed to

carry out the steps shown in the flow chart of Figure 5 while maintaining substantially the same functionality without departing from the scope and spirit of the present invention.

Figure 6 is a simplified diagram showing a cable 150 in accordance with the present invention which includes a memory 156. Cable 150 includes Kelvin connections 152 and 154. Each Kelvin connection 152, 154 includes a pair of electrical terminals which are configured to couple to a terminal of battery 12. The Kelvin connection can be used by an electronic battery tester to measure a dynamic parameter of battery 12. In one embodiment connectors 15X and 15Y are single connections and do not provide a Kelvin connection. Cable 150 includes electrical terminals 158 which are configured to couple to electrical terminal 160 of a battery tester 170. Battery tester 170 includes memory circuitry 172 which is configured to communicate, either bi-directionally or uni-directionally, with memory 156. Battery tester 170 is configured to provide a battery tester output 174 related to the condition of battery 12.

Cable 150 also includes optional connectors or sensors 180 which may be included for use in testing battery 12. For example, sensor 180 may be a current probe, temperature sensor, bar code scanner, or other device.

Memory 156 can be permanent memory which is, for example, written to during manufacture, or it can be memory which is written to during use. For example, memory 156 can comprise an EEPROM or other type of memory. Memory 156 may be powered through the connection to see tester 170 or through some other technique such as a battery, or through power received from the battery under test 12. In some embodiments, the connection between memory 156 and memory circuitry 172 is a non-physical connection which is an optical, RF, inductive, capacitive, ultrasonic, or other type of wireless connection.

Memory 156 can be used for any number of purposes and is not limited to those specifically disclosed herein. Memory 156 can contain calibration parameters which are used to calibrate measurements performed by tester 170 when using cable 150. Such parameters can be programmed during manufacture of cable 150. Such calibration parameters can also be stored during operation, for example through a calibration procedure, in which the cable 150 is calibrated against a standard cable or other reference. During the calibration procedure the calibration parameters are written to memory 156 for subsequent use. The calibration parameters can be indicative of resistance of values within cable 150, inductive values, capacitive values, etc.

Memory 156 may contain information which describes the physical configuration of cable 150.

For example, memory 156 can provide an indication that cable 150 contains Kelvin connections 152 and 154, a sensor 180, or other sensors or connections. The data can identify the type of sensor which sensor 180 comprises Such information can be used by tester 170 during the battery testing procedure. If an incorrect cable is in use, the tester 170 can provide a message or other warning to the operator which indicates that an alternative cable should be coupled to tester 170.

Memory 156 can contain a serial number which uniquely identifies cable 150. The serial number can be used for warranty returns in order to allow a manufacture to identify which cable is being returned. Further, the battery tester 170 can read the serial number stored in memory 156. Tester 170 can prevent measurements from being made if the serial number indicates the cable is an improper cable or can store the serial number such that tester 170 contains a record of which cables it has been used with.

Memory 156 can contain a counter (memory location) which counts the number of times it has been put into use or the number of tests that have been performed. Such information can be used to suggest that the cable should be replaced or used for diagnostic information. For example, if the number of tests has grown relatively large, tester 170 can

inform the operator that the cable 150 should be replaced.

Memory 156 can also store the serial number of tester 170. Such information can be used to provide a record of which testers 170 a cable 150 has been connected to.

Memory 156 can store information related to the date it is first placed into service and/or the date of subsequent tests. Memory 156 can also store information related to the types of batteries tested or the number of missed. For example, the memory contain a statistical value or a number related to the number of connections which failed to properly connect to the battery. This can be an indication that the connection or contacts have worn, that the wires are failing or that springs in the clamp are failing. This information can be communicated to a user to provide an indication that the cable should be replaced soon. When there is an error in the measurements performed by tester 170, or some other type of error, error codes can be written into memory 156 for use in subsequent diagnostics. Memory 156 can also contain encrypted information to prevent tampering. For example, memory 156 can contain a special key which cannot be easily reproduced. Tester 170 can be configured to only operate if an appropriate key is read back from memory 156. In another example, the mode of operation of the tester can be changed based upon a value stored in the

cable. For example, if the memory and the cable indicates that the cable includes a current probe, electrical circuitry in the tester can be configured to automatically begin the testing operation. On the other hand, if a value stored in the memory indicates that the cable includes a clamp, the electronic circuitry in the tester can give an option to the operator to either automatically start the testing operation or start upon actuation of a switch or other input.

Although the present invention has been described with reference to preferred embodiments, workers skilled in the art will recognize that changes may be made in form and detail without departing from the spirit and scope of the invention.